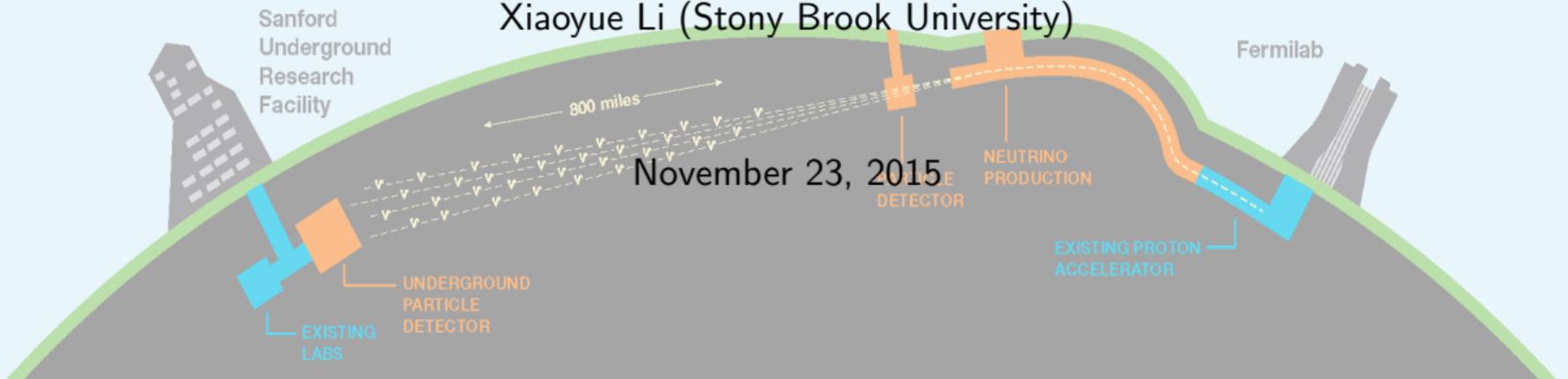


## Wire-Cell Reconstruction Update

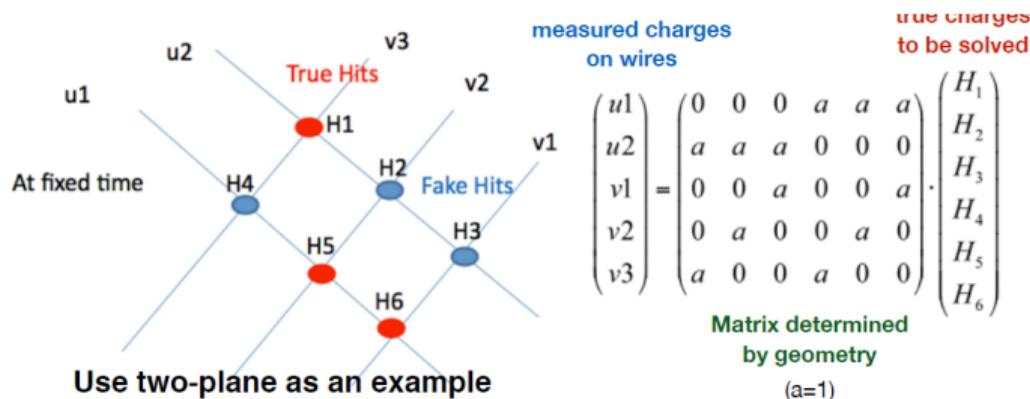
Xin Qian (BNL),  
Brett Viren (BNL),  
Chao Zhang (BNL),

Xiaoyue Li (Stony Brook University)



# Wire-Cell Reconstruction I

- ▶ <https://indico.fnal.gov/getFile.py/access?contribId=78&sessionId=21&resId=0&materialId=slides&confId=10100>
- ▶ Due to wire readout, the measured information is reduced from  $\sigma(N^2)$  to  $3N$ , causing degeneracy.
- ▶ Same charge in a voxel is measured 3 times by wires on the three wire planes.
- ▶ Equation between measured charge on wires and potentials hits can be formed. Fake hits should be assigned  $\sim 0$  charge if equation can be solved.



## Wire-Cell Reconstruction II

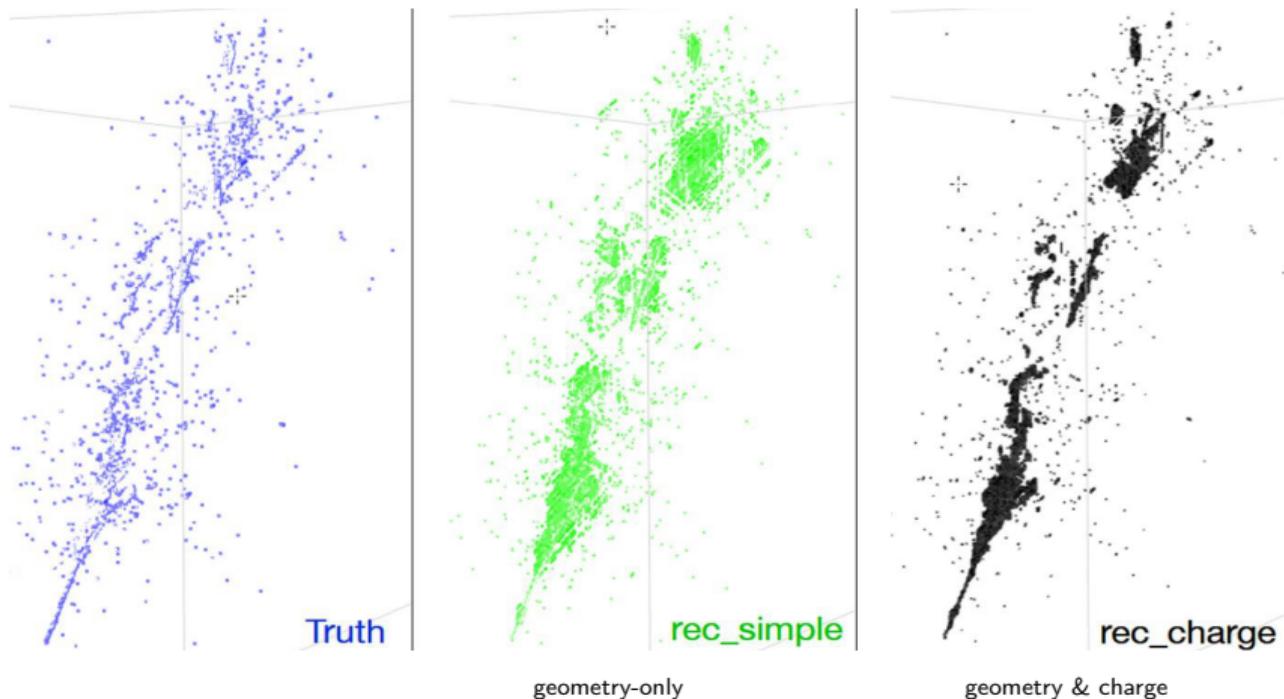
- ▶ Form time slices (2  $\mu\text{s}$  time bins instead of traditional Gaussian hits, and charge in a time slice on a wire is the sum of its de-convoluted signals)
- ▶ Construct Wire-Cell association
- ▶ Merge adjacent cells into “blobs”
- ▶ Construct  $\chi^2$
- ▶ Obtain best matched 3D space points through  $\chi^2$  minimization.
  - ▶ When equation cannot be solved, other algorithms are developed to find minimum  $\chi^2$ .
- ▶ Clustering and tracking...

$$\chi^2 = (B \cdot W - G \cdot C)^T V_{BW}^{-1} (B \cdot W - G \cdot C)$$
$$\frac{\partial \chi^2}{\partial C} = 0 \Rightarrow C = (G^T V_{BW}^{-1} G)^{-1} G^T V_{BW}^{-1} B W$$

- ▶  $C$ : charge in each blob (merged cell) to be solved
- ▶  $G$ : geometry matrix connecting blobs and wires
- ▶  $W$ : charge in each single wire
- ▶  $B$ : Geometry matrix connecting merged wires and single wires
- ▶  $V_{BW}$ : covariance matrix describing uncertainty in wire charge

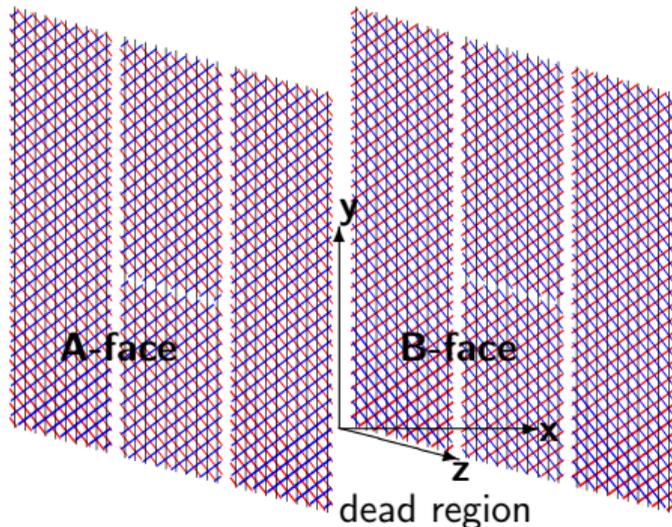
# Wire-Cell Reconstruction III

Example: a 1.5 GeV electron

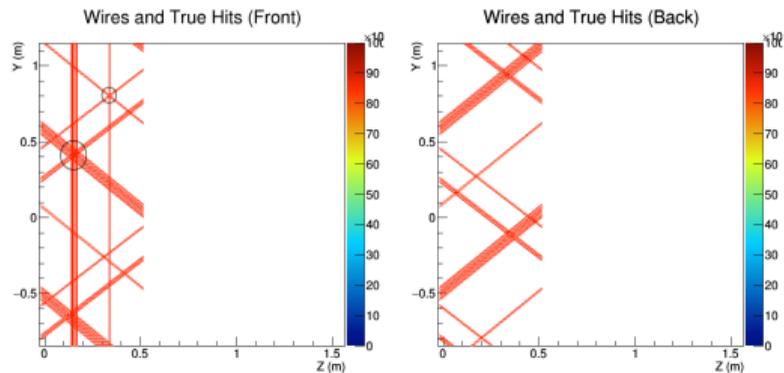


# New developments: parametrized wire-wrapping I

- ▶ Wires can be constructed given a few parameters:
  - ▶ Number of APAs in each cryostat
  - ▶ 3D size of each APA
  - ▶ Two wire angles and three wire pitches



- ▶ A charge is drifted to the nearest APA; any charge deposits in the middle of an APA are simply ignored.
- ▶ Gaps between any two APAs are treated as dead region as well.
- ▶ A charge can fire multiple U/V wire segments in both A-face and B-face.



## New developments: parametrized wire-wrapping II

- ▶ In the case of wrapped wire, wires in the original algorithms are largely replaced by channels.
  - ▶ before: cells that have one or more common edges are merged into one blob; wires associated with these cells are grouped accordingly
  - ▶ after: cells are constructed and merged in the same way as before according to the geometry; wires associated with merged cells are also merged, and association between merged wires and single channel is constructed.

$$\chi^2 = (B \cdot W - G \cdot C)^T V_{BW}^{-1} (B \cdot W - G \cdot C)$$
$$\frac{\partial \chi^2}{\partial C} = 0 \Rightarrow C = (G^T V_{BW}^{-1} G)^{-1} G^T V_{BW}^{-1} B W$$

- ▶  $C$ : charge in each blob (to be solved)
- ▶  $G$ : geometry matrix connecting blobs and merged wires
- ▶  $W$ : charge in each single **channel**
- ▶  $B$ : Geometry matrix connecting merged wires and single **channels**
- ▶  $V_{BW}$ : covariance matrix describing uncertainty in **channel** charge

# Wire-Cell on 35ton I

<http://www.phy.bnl.gov/wire-cell/bee/set/ee2fd0e7-98e7-49b5-951e-a724a10395df/event/0/>

The screenshot displays the Wire-Cell visualization interface. The main window shows a 3D reconstruction of the detector structure, with tracks overlaid. The interface includes several control panels:

- Top Bar:** BEE for Wire-Cell, Event 1 - 0 - 1, Camera, View, System.
- Left Panel:** Controls for the 'truth' overlay, including Size (slider from 1 to 8), Opacity (slider from 0 to 1), and Plain Color (color picker).
- Right Panel (Controls):**
  - General:** Event (0), Display (WireCell-charge), Theme (dark), Show Charge (checked), Show TPCs (checked), Show Axes (unchecked), Color Scale (1).
  - Recon:** 1. WireCell-charge, 2. truth, 3. WireCell-simple.
  - Camera:** Center to Event, Ortho Camera (unchecked), 2D View (YZ), Reset.
- Bottom Right:** Close Controls, slice #: 0 | slice x: 0.

# Wire-Cell on 35ton II

<http://www.phy.bnl.gov/wire-cell/bee/set/3e880ad-507e-4f55-8454-caae665482bb/event/0/>

The screenshot displays the Wire-Cell visualization interface. The main window shows a 3D detector model with particle tracks. The tracks are color-coded and labeled with 'truth'. The interface includes a top navigation bar with 'BEE for Wire-Cell', 'Event 1 - 0 - 1', 'Camera', 'View', and 'System' menus. On the left, there are controls for 'truth' (Size, Opacity, Plain Color) and a 'Close Controls' button. On the right, there is a 'General' panel with settings for Event (0), Display (WireCell-charge), Theme (dark), Show Charge (checked), Show TPCs (checked), Show Axes (unchecked), and Color Scale (1). Below the General panel is a 'Recon' panel with a list of layers: 1. WireCell-charge, 2. truth, and 3. WireCell-simple. Further down are 'Slice' and 'Camera' panels, with 'Center to Event' checked, 'Ortho Camera' unchecked, and '2D View' set to 'YZ'. A 'Reset' button is also present. The bottom right corner shows 'slice #: 0 | slice x: 0'.

# Wire-Cell on 35ton III

<http://www.phy.bnl.gov/wire-cell/bee/set/451b9c39-3312-4aec-a07c-9376ba6b12c8/event/0/>

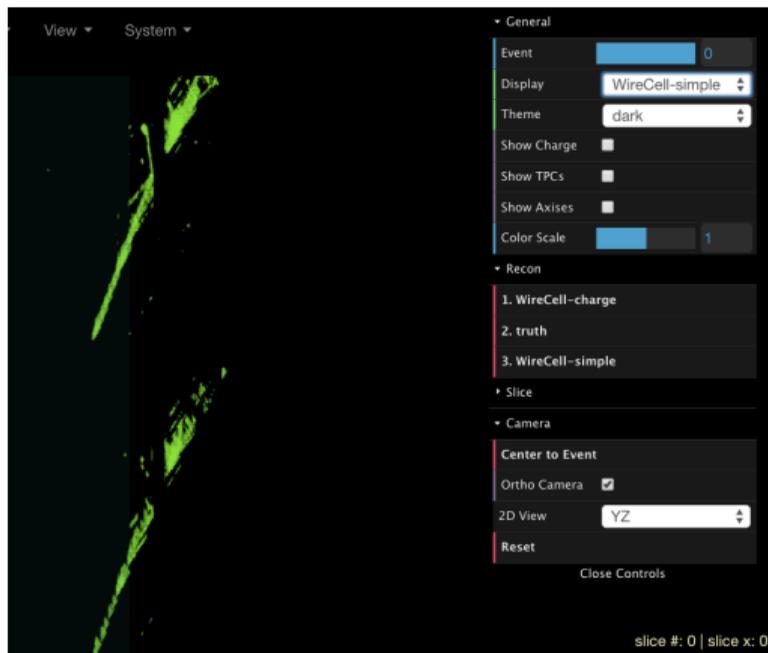
The screenshot displays the Wire-Cell visualization interface. The main window shows a 3D reconstruction of the detector structure, with a central track visualization colored in blue and yellow. The interface includes several control panels:

- General:** Event (0), Display (WireCell-charge), Theme (dark), Show Charge (checked), Show TPCs (checked), Show Axes (unchecked), Color Scale (1).
- Recon:** 1. WireCell-charge, 2. truth, 3. WireCell-simple.
- Camera:** Center to Event (checked), Ortho Camera (unchecked), 2D View (YZ), Reset button.

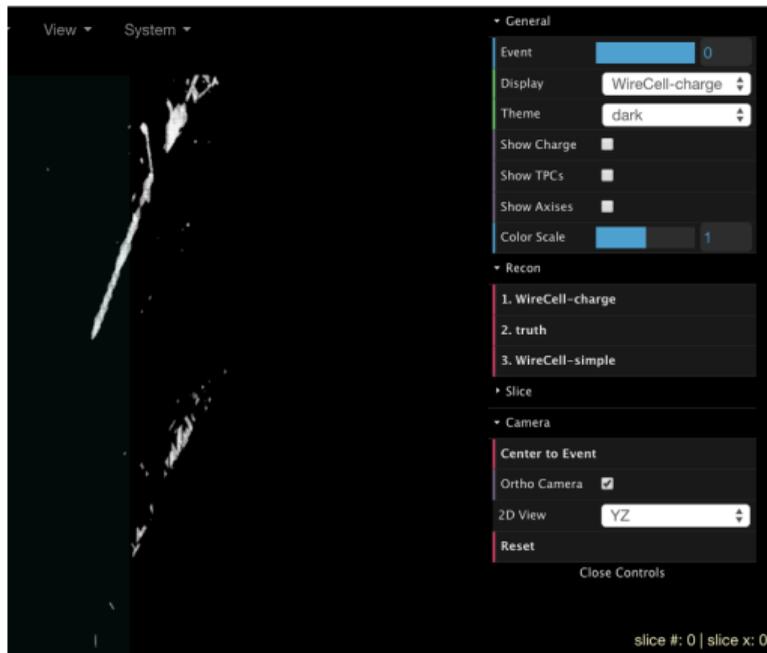
On the left side, there are controls for the 'truth' layer: Size (slider from 1 to 8), Opacity (slider from 0 to 1), and Plain Color (red color swatch).

At the bottom right, the status bar indicates 'slice #: 0 | slice x: 0'.

# Wire-Cell on 35ton IV



geometry-only



geometry & charge

100 more events: <http://www.phy.bnl.gov/wire-cell/bee/set/20/event/list/>

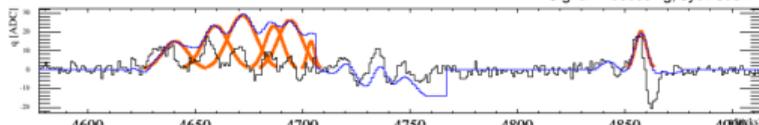
## Further studies

- ▶ Validation of wire parametrization using MicroBooNE results.
- ▶ Use Wire-Cell to analysis 35ton data.
- ▶ The implimentation of wrapped wire in Wire-Cell enables studies of far detector optimization:
  - ▶ wire pitch 3 mm vs 5 mm
  - ▶ wire angle (and consequently how many times a certain wire is wrapped)
  - ▶ effects of wire wrapping on reconstruction
  - ▶ effects of dead channel
  - ▶ orientation of detector w.r.t. beam
- ▶ Possible improvements to Wire-Cell:
  - ▶ Develop cuts to futher remove fakes hits due to wire wrapping
  - ▶ Fix the gap in inital clustering
  - ▶ Faster/better equation-solving

# BACKUP

## Definition of Time Slice

Signal Processing, Jyoti Joshi



- In Wire-Cell reconstruction, we don't use the traditional concept of "Gaussian Hits".
  - Avoids the complications in fitting the waveform (especially for a long signal)
- Instead, we simply define a time slice as a 2-us bin
  - Binning choice matches the shaping time
- Charge in a time slice on a wire is the sum of its deconvoluted signals

## Wires, Cells and Blobs

- **Wire**: a Wire represents a  $\pm$  pitch/2 rectangular region centered around the wire
- **Cell**: a Cell is the overlap region of three Wires. This is the smallest area unit on a plane.
- **Blob**: group of hit cells that are adjacent
  - Merge cells into blob to reduce degeneracy

